PHENOLOGY AND DISTRIBUTION OF CADDISFLIES (TRICHOPTERA) IN OAK CREEK, A HIGH-DESERT PERENNIAL STREAM IN ARIZONA

DEAN W. BLINN* AND DAVID E. RUITER

Department of Biological Sciences, Northern Arizona University, Flagstaff, AZ 86011 (DWB)
6260 South Grant Street, Centennial, CO 80121 (DER)
**Correspondent: deandiacad@comcast.net*

ABSTRACT—We collected 58 species of caddisflies representing 30 genera and 16 families during a 5-year period in Oak Creek, Coconino Co., Arizona. This is the largest number of species of caddisflies reported in any drainage in Arizona and includes >50% of species reported from the state. Species assemblages changed dramatically along the 767-m descent of Oak Creek over a 70-km distance. Discharge records suggest reduced winter and spring surges of water and increased embeddedness of the channel have caused changes in assemblages of caddisflies in Oak Creek over the past several decades. Increased numbers of hydroptilids, hydropsychids, and leptocerids have replaced limnephilids. We conducted a 2-year phenological study at monthly intervals at two sites separated by <400 m in elevation and a distance of 14 km. Spring surges of water played a selective role in larval success and ultimately in number and composition of captures of adults between years. We increased the number of recorded species of caddisflies to 109 in the state. A baseline on assemblages of caddisflies was provided for monitoring changes in health of ecosystem in Oak Creek during the predicted, long-term drought in the Southwest.

RESUMEN—Cincuenta y ocho especies de Tricóptera de 30 géneros y 16 familias fueron colectadas durante un período de 5 años en Oak Creek, condado de Coconino, Arizona, EE.UU. Ésta es la más alta cantidad de especies de Tricóptera reportada en cualquier desagüe en Arizona e incluye > 50% de las especies reportadas en el estado. Los ensamblajes de especies cambiaron dramáticamente a lo largo del descenso de 767 metros en la distancia de 70 kilómetros de Oak Creek. Registros de descarga sugieren inundaciones invernales y primaverales reducidas y el aumento de la sedimentación del lecho han cambiado los ensamblajes de Tricóptera en Oak Creek en las últimas décadas Números mayores de individuos de hydroptilidae, hydropsychidae, y leptoceridae han reemplazado limnephilidae. Un estudio fenológico de dos años fue conducido en intervalos mensuales en dos sitios separados de < 400 m de elevación y una distancia de 14 km. Inundaciones primaverales tuvieron un papel de selección en el éxito de la larva y eventualmente en la composición y el número de adultos capturados entre años. Se aumentó el número de especies de Tricóptera registradas en el estado a 109. Se proveyeron datos de base de ensamblajes de Tricóptera para monitorear cambios en la salud del ecosistema en Oak Creek durante la sequía pronosticada a largo plazo en el suroeste de los EE.UU.

There are few published studies on distribution of aquatic insects in Arizona although the state has a variety of perennial and ephemeral streams meandering through mountainous regions to low desert landscapes (Blinn and Poff, 2005). Houghton (2001) reported 51 species of caddisflies in 14 stream sites in the Apache National Forest in eastern Arizona, and Blinn and Ruiter (2006) recorded 104 species in 93 stream sites throughout Arizona.

Oak Creek is a major tributary of the Verde River and is one of a few perennial streams in the high-desert region of the Southwest. Historically, snowmelt delivered high spring flows (February–April) through Oak Creek, but these events are becoming fewer due to reduced snowfall in the region (http://www.wcc.nrcs.usda.gov/snotel). Spring flows in Oak Creek averaged 4.1 $m^3 s^{-1}$ (*SE* ± 1.7) over the past decade compared to nearly 7.1 $m^3 s^{-1}$ (*SE* ± 1.7) over the previous 3 decades (http://waterdata.usgs.gov/nwis). Furthermore, annual precipitation and discharge have decreased by 9 cm and 0.6 $m^3 s^{-1}$, respectively, in the past decade. Hereford (2007) also reported winter moisture has been below average in 11 of the past 12 years in Flagstaff. Maximum

TABLE 1—Location, elevation (m), and percentage embeddedness of channel at seven sites along Oak Creek, Coconino Co., Arizona.

Site	Location	Elevation (m)	Embeddedness (%)
Sterling Springs Fish Hatchery	35°01.48N, 111°44.30W	1,820	<25
Pumphouse Wash	35°15.10N, 111°44.10W	1,731	<25
Pine Flats Campground	35°01.67N, 111°73.94W	1,676	<25
West Fork Confluence	34°59.45N, 111°44.05W	1,647	<25
Indian Gardens	34°91.39N, 111°72.64W	1,401	25–50
Sedona	34°51.36N, 111°47.21W	1,372	25–50
Page Springs	34°45.89N, 111°45.08W	983	51–75

flows in Oak Creek over the past half-century were recorded in February 1980 when floodwaters reached nearly 748 $m^3 s^{-1}$ (Tadayon et al., 2001). These periodic floods are instrumental in the community structure and ecological processes in desert streams such as Oak Creek (Fisher and Grimm, 1988). Presently, Oak Creek has one of the highest diversities of aquatic insects in the state (P. Spindler, in litt.).

There were several earlier studies on aquatic insects in Oak Creek (May, 1972; Parrott, 1975; Scott, 1982; Dehoney and Gaud, 1983), and more recently by Moulton et al. (1994). These studies were based on larval determinations or one-time collections. M. W. Sanderson made extensive light-trap collections in Oak Creek during 1976–1984. Specimens are housed in the Illinois Natural History Survey in Champaign.

There is no published phenological study on caddisflies in the southwestern United States. However, Bowles et al. (2007) studied distribution of assemblages of caddisflies in eight large springs and spring-runs in central Texas. We examined phenology of adult caddisflies in Oak Creek at monthly intervals at two elevations during January 2002–December 2003. Discharge of stream, temperature of water and air, and embeddedness of channel were measured during each site visit. We also sampled assemblages at five additional elevations from headwaters of Oak Creek to <10 km of its mouth at the Verde River during 2001–2005. Comparisons of health of the channel based on assemblages of caddisflies according to levels of tolerance established by Barbour et al. (1999) and Blinn and Ruiter (2006) are discussed. An updated list of species and phenology of selected taxa are provided as a baseline for future inventories in this vulnerable aquatic resource. The Oak Creek system, as well as other streams, may be in jeopardy based on the extended drought predicted for the American Southwest by Seager et al. (2007).

MATERIALS AND METHODS—Oak Creek flows through Oak Creek Canyon and rapidly descends 767 m over 70 km from its headwaters at Sterling Springs to its mouth at the Verde River. Spring flows were <3 $m^3 s^{-1}$ during the study, except in March 2003 and February 2005, when flows reached 50 and 163 $m^3 s^{-1}$, respectively (http://waterdata.usgs.gov/nwis). Summer base flows were typically <1 $m^3 s^{-1}$.

Table 1 provides locations and embeddedness of channel for seven sites examined at different elevations along Oak Creek during 2001–2005. Dramatic changes in predators, canopy cover, and characteristics of the channel occur along the 70-km gradient. Omnivores such as crayfish (*Orconectes virilis*) increase downstream from Indian Gardens to the mouth. Predaceous brown (*Salmo trutta*) and rainbow (*Oncorhynchus mykiss*) trout are abundant in upper sites of Oak Creek, while largemouth bass (*Micropterus*) and carp (*Cyprinus carpio*) are common at the lowest site (Aitchison, 1989). Riparian communities change from alder (*Alnus oblongifolia*), Fremont cottonwood (*Populus fremontii*), and Douglas-fir (*Pseudotsuga menziesii*) with nearly 100% canopy cover at the upper sites to sycamore (*Plantanus wrightii*), Gambel oak (*Quercus gambelii*), and alder with <50% cover at Sedona, Coconino Co., Arizona, to a semi-desert grassland with little canopy near the mouth.

Temperatures of water and air were measured with a hand-held thermometer during each site visit and general weather conditions were recorded. Embeddedness of channel was visually grouped into the following categories at each site: 1, <25%; 2, 25–50%; 3, >50–75%; 4, >75%. Stream flow was obtained at site 09504420 of the United States Geological Survey (http://waterdata.usgs.gov/nwis). This site was ca. 23 km from the source and 50 km upstream from the mouth.

Adult caddisflies were collected with a vertical, 30-cm, 8-watt, portable, ultraviolet light over a 19-L, white porcelain bucket during June and July 2001–2005. Light traps were placed near the stream 1 h after sunset and retrieved after 3–4 h. All collections were placed into 70% ethanol and sorted in the laboratory.

Monthly collections were made at Pumphouse Wash and Indian Gardens during January 2002–December 2003 to monitor number and species of adults.

Sampling occurred mid-month during clear weather at flows $<1\ m^3\ s^{-1}$, except on 12 September and 13 November 2002, when flows were ca. 10–11 $m^3\ s^{-1}$. Differences in monthly temperatures of water and air were compared between years with a Student's *t*-test with SYSTAT software (Wilkinson, 1989). A Sørensen similarity index (Sørensen, 1948) was compared between collections of caddisflies made by Sanderson (1976–1984) and this study, and between assemblages for sites along Oak Creek.

RESULTS—From >6,000 specimens at seven sites along Oak Creek, Arizona, 58 species of caddisflies representing 30 genera and 16 families were identified (Table 2). Species richness of caddisflies was greatest (40 taxa) at Indian Gardens and lowest (14 taxa) at Pine Flats campground (Table 2). *Cheumatopsyche arizonensis* and *Helicopsyche borealis* occurred at all seven sites, while *Atopsyche sperryi*, *Ceratopsyche oslari*, *Hydroptila arctia*, and *H. hamata* occurred at six sites along Oak Creek.

Hydroptilidae and Hydropsychidae were the most diverse and abundant families throughout Oak Creek (Table 2). Helicopsychidae and Sericostomatidae were numerically important at upper sites, while Hydropsychidae and Hydroptilidae were important at lower elevations. Species dominance changed from *Ceratopsyche venada*, *Gumaga griseola*, and *H. mexicana* at higher elevations to *C. arizonensis*, *Hydropsyche auricolor*, and *Hydroptila ajax* at lower elevations. Intermediate elevations were dominated by *H. borealis*, *H. arctia*, and *H. hamata*. *Helicopsyche mexicana* occurred at the top five sites, but was absent at the lower two sites (Table 2). *Leucotrichia limpia*, *M. nobsca*, *N. dorsalis*, *O. nigritta*, and *P. balmorhea* were collected only at the lowest site with the highest embeddedness and warmest water (Tables 1 and 2). Embeddedness in Oak Creek ranged from <25% at upper sites to nearly 75% at the lowest site (Table 1). Water temperatures ranged from 8°C at the highest site in winter to 23°C at the lowest site in summer.

No significant ($P < 0.001$) difference was recorded in annual monthly water and air temperatures between Pumphouse Wash and Indian Gardens during 2002 and 2003, but Indian Gardens had 5–7°C higher air temperatures at onset of emergence periods in April and May and higher embeddedness of channel (Table 1). Mean annual water temperature for both sites was 13.2°C; mean air temperature was 13.2°C (±1.5 *SE*) for Pumphouse Wash and 17.6 °C (±1.6 *SE*) for Indian Gardens. No adult caddisfly was collected at air temperatures <12°C.

Sørenson's similarity index (was 0.545 for assemblages of caddisflies between Sanderson's earlier collections (1976–1984) and our collections (2001–2005) in Oak Creek. Sørenson's similarity index between Pumphouse Wash and Indian Gardens was 0.649, and between Pumphouse Wash and the lowest site at Page Springs was 0.271. The most significant drop in Sørenson's similarity index (0.300) in Oak Creek was between Sedona and Page springs.

Adult caddisflies were captured only May–October at Pumphouse Wash and April–October at the lower Indian Gardens site (Table 3). Overall lower numbers of adults were collected at Pumphouse Wash (1,378) than at Indian Gardens (3,648) with 29 species at Pumphouse Wash and 35 at Indian Gardens during 2002 and 2003. Lepidostomatids and limnephilids had higher rates of capture at Pumphouse Wash, while hydropsychids had higher rates of capture of adults at Indian Gardens (Table 3).

Distinct spatial patterns also occurred within genera between sites (Table 3). *Helicopsyche mexicana* had more captures at Pumphouse Wash, but *H. borealis* had higher captures at Indian Gardens (Table 3). *Hydroptila arctia* had high rates of capture at Pumphouse Wash and Indian Gardens, but *H. hamata* was more common at Indian Gardens. Also, *Culoptila moselyi*, *G. griseola*, and *Limnephilus lithus* were nearly restricted to the upper Pumphouse Wash site, while *H. auricolor*, and *H. occidentalis*, and *Wormaldia arizonensis* were nearly restricted to the lower Indian Garden site over the 2-year period (Table 3).

Although there was no significant difference in temperatures of water and air between years at either site during 2002 and 2003, there was a striking difference in discharge. Discharge remained near 0.01 $m^3\ s^{-1}$ during winter and spring 2002, but reached 47 $m^3\ s^{-1}$ in mid-February and 50 $m^3\ s^{-1}$ in mid-March 2003 (http://waterdata.usgs.gov/nwis).

Lower numbers of adults were collected at both sites in 2002 (1,927) compared to 2003 (3,105) following the March surge of water. Numbers of adults captured in June 2002 were 112 and 389 at Pumphouse Wash and Indian Gardens, respectively, compared to 272 and 550 adults in June 2003. Numbers of adults captured at Pumphouse Wash (215) and Indian Gardens

TABLE 2—Relative frequency (%) of occurrence of adult caddisflies at seven sites in Oak Creek, Coconino Co., Arizona, June 2001–2005.

Taxon	Sterling Springs Fish Hatchery (n = 2)	Pumphouse Wash (n = 4)	Pine Flats Campground (n = 2)	West Fork Confluence (n =2)	Indian Gardens (n = 4)	Sedona (n = 2)	Page Springs (n = 3)
Apataniidae							
Apatania arizona	X[a]	X	X				
Calamoceratidae							
Phylloicus mexicanus[b]		X	X	X	X		
Glossosomatidae							
Agapetus boulderensis			X[a]				
Culoptila kimminsi[b]				X			
C. moselyi		X					
Glossosoma ventrale[b]		X	X[a]	X	X		
Protoptila balmorhea[b]							X
P. erotica		X		X	X	8	3
Helicopsychidae							
Helicopsyche borealis[b]	X	X	26	22	14	X	X
H. mexicana	X	16	23	6	X		
Hydrobiosidae							
Atopsyche sperryi	X[a]	X	X	X	X	X	
A. tripunctata[b]					X		
Hydropsychidae							
Ceratopsyche oslari	X	X	X	X	X		X
C. venada	26	X		X	X		
Cheumatopsyche arizonensis	X	12	27	X	21	20	X
C. pinula		X			19	11	
Hydropsyche auricolor					X	4	37
H. occidentalis				X	8	9	5
Smicridea arizonensis[b]						X	X[a]
S. dispar[b]		X			X		X
S. fasciatella[b]					X		

TABLE 2—Continued.

Taxon	Sterling Springs Fish Hatchery (n = 2)	Pumphouse Wash (n = 4)	Pine Flats Campground (n = 2)	West Fork Confluence (n =2)	Indian Gardens (n = 4)	Sedona (n = 2)	Page Springs (n = 3)
Hydroptilidae							
Hydroptila ajax[b]	X	X			X	14	19
H. arctia[b]	17	8		16	X	X	X
H. hamata	X	X		15	15	11	X
H. icona[b]	X[a]						X
H. rono[b]	X	X			X		
Ithytrichia clavata[b]	X[a]						
I. mexicana[b]		X	X	X			
Leucotrichia limpia[b]							X
Neotrichia okopa[b]					X		
Ochrotrichia dactylophora	X	31		X	X	X	
O. ildria	X[a]	X			X		
O. (*Metrichia*) *nigritta*[b]							X
O. quadrispina	X[a]				X	X	X[a]
O. stylata[b]	X[a]			X	X	X	4
O. tarsalis		X					3
Lepidostomatidae							
Lepidostoma aporna[b]				11			
L. knulli[b]		X		X	X	X	
Leptoceridae							
Nectopsyche dorsalis[b]							X
N. stigmatica[b]					X		X
Oecetis arizonica		X					
O. avara					X	X	4
O. disjuncta[b]	X	X	X	X	X		
Limnephilidae							
Hesperophylax magnus		X	X	X		X	
Limnephilus lithus		X	X	X			
Odontocedridae							
Marilia flexuosa					X		
M. nobsca							X

TABLE 2—Continued.

Taxon	Sterling Springs Fish Hatchery (n = 2)	Pumphouse Wash (n = 4)	Pine Flats Campground (n = 2)	West Fork Confluence (n =2)	Indian Gardens (n = 4)	Sedona (n = 2)	Page Springs (n = 3)
Philopotamidae							
Chimarra primula		X			X		
C. ridleyi[b]						X	X
C. utahensis	X			X	X	X	X
Wormaldia arizonensis[b]					X		X
Polycentropodidae							
Polycentropus arizonensis	X[a]	4		X	X		
P. gertschi		X					
P. halidus	X	X		X	X	X	
Psychomyiidae							
Psychomyia flavida[b]		X		X	X	X	
Tinodes provo[b]				X	X		
Rhyacophilidae							
Rhyacophila coloradensis	X[a]	X		X	X		
Sericostomatidae							
Gumaga griseola[b]	33	5	X	7	X		
Number of taxa	24	34	14	28	40	21	25

[a] Not collected in this study, but collected in June 1993 by Moulton et al. (1994).
[b] Not collected by M. W. Sanderson during 1976–1984.

TABLE 3—Comparison of relative frequency (%) of selected species of caddisflies collected at two sites in Oak Creek, Coconino Co., Arizona, 2002 and 2003.

	April		May		June		July		August		September		October	
Site and taxon	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Pumphouse Wash														
Glossosomatidae														
Culoptila moselyi	—	—	0	0	1	<1	0	0	<1	0	20	0	0	0
Helicopsychidae														
Helicopsyche borealis	—	—	0	0	<1	0	2	2	0	0	0	0	0	0
H. mexicana	—	—	0	0	36	26	4	8	23	19	0	2	0	0
Hydrobiosidae														
Atopsyche sperryi	—	—	100	0	<1	1	0	<1	4	3	0	5	0	35
Hydropsychidae														
Ceratopsyche oslari	—	—	0	0	<1	1	0	4	14	0	0	0	0	0
C. venada	—	—	0	0	<1	8	3	6	5	10	80	10	0	0
Cheumatopsyche arizonensis	—	—	0	0	34	<1	0	2	2	0	0	0	0	0
C. pinula	—	—	0	0	0	<1	0	<1	2	0	0	0	0	0
Hydropsyche auricolor	—	—	0	0	0	0	0	0	0		0	0	0	0
H. occidentalis	—	—	0	0	0	<1	0	0	0	0	0	0	0	0
Hydroptilidae														
Hydroptila arctia	—	—	27	0	2	41	6	39	16	27	0	2	0	0
H. hamata	—	—	0	3	2	0	0	2	0	0	0	0	0	2
Ithytrichia mexicana	—	—	0	0	0	<1	0	2	11	4	0	0	0	0
Ochrotrichia dactylophora	—	—	0	0	0	0	77	0	0	1	0	0	0	0
O. ildria	—	—	0	0	0	0	0	0	9	0	0	0	0	0
O. quadrispina	—	—	0	0	0	0	0	0	0	0	0	0	0	0
Lepidostomatidae														
Lepidostoma knulli	—	—	9	0	4	<1	<1	0	4	0	0	11	0	8
Leptoceridae														
Oecetis disjuncta	—	—	0	0	0	4	0	<1	0	<1	0	5	0	0
Limnephilidae														
Limnephilus lithus	—	—	0	0	2	1	0	<1	0	0	5	0	0	39

TABLE 3—Continued.

Site and taxon	April		May		June		July		August		September		October	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Philopotamidae														
Chimarra utahensis	—	—	0	0	0	0	2	4	0	0	0	0	0	0
Wormaldia arizonensis	—	—	0	0	0	0	0	0	0	0	0	0	0	0
Polycentropodidae														
Polycentropus arizonensis	—	—	0	0	1	2	3	5	11	24	0	8	0	4
Sericostomatidae														
Gumaga griseola	—	—	0	0	5	12	<1	0	4	<1	0	0	0	0
Indian Gardens														
Glossosomatidae														
Culoptila moselyi	0	0	0	0	0	0	0	0	<1	0	0	0	0	0
Helicopsychidae														
Helicopsyche borealis	0	0	40	2	45	31	8	12	0	3	2	0	0	0
H. mexicana	0	0	0	0	<1	<1	1	1	1	<1	0	2	0	0
Hydrobiosida														
Atopsyche sperryi	<1	0	0	<1	<1	<1	0	<1	4	3	0	5	0	0
Hydropsychidae														
Ceratopsyche oslari	3	1	0	<1	0	0	0	0	0	0	1	0	0	0
C. venada	3	0	0	0	1	1	0	0	1	0	1	1	20	0
Cheumatopsyche arizonensis	0	31	34	40	11	13	38	35	22	23	31	27	40	30
C. pinula	70	44	6	38	12	40	21	<1	9	41	20	14	0	0
Hydropsyche auricolor	4	0	8	1	8	1	<1	<1	1	3	3	3	0	20
H. occidentalis	0	0	12	4	12	0	3	20	4	3	7	11	0	7
Hydroptilidae														
Hydroptila arctia	0	0	0	5	3	5	3	6	15	0	0	<1	0	0
H. hamata	3	0	3	0	2	3	17	7	29	17	25	41	20	0
Ithytrichia mexicana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochrotrichia dactylophora	0	0	0	0	1	<1	<1	<1	2	1	0	<1	0	0
O. ildria	4	<1	0	0	0	0	<1	0	<1	0	0	0	0	0
O. quadrispina	<1	<1	0	0	0	0	2	0	<1	0	2	0	0	0

TABLE 3—Continued.

Site and taxon	April		May		June		July		August		September		October	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Lepidostomatidae														
Lepidostoma knulli	0	3	0	1	<1	0	0	0	<1	0	1	0	0	3
Leptoceridae														
Oecetis disjuncta	0	0	0	<1	0	<1	0	<1	0	<1	0	<1	0	0
Limnephilidae														
Limnephilus lithus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Philopotamidae														
Chimarra utahensis	0	0	0	0	<1	4	2	4	4	5	1	0	0	0
Wormaldia arizonensis	0	0	0	0	0	0	<1	0	<1	<1	2	1	10	0
Polycentropodidae														
Polycentropus arizonensis	0	0	0	3	0	0	0	0	<1	0	0	0	0	7
Sericostomatidae														
Gumaga griseola	0	0	0	0	0	0	0	0	0	0	0	<1	0	0

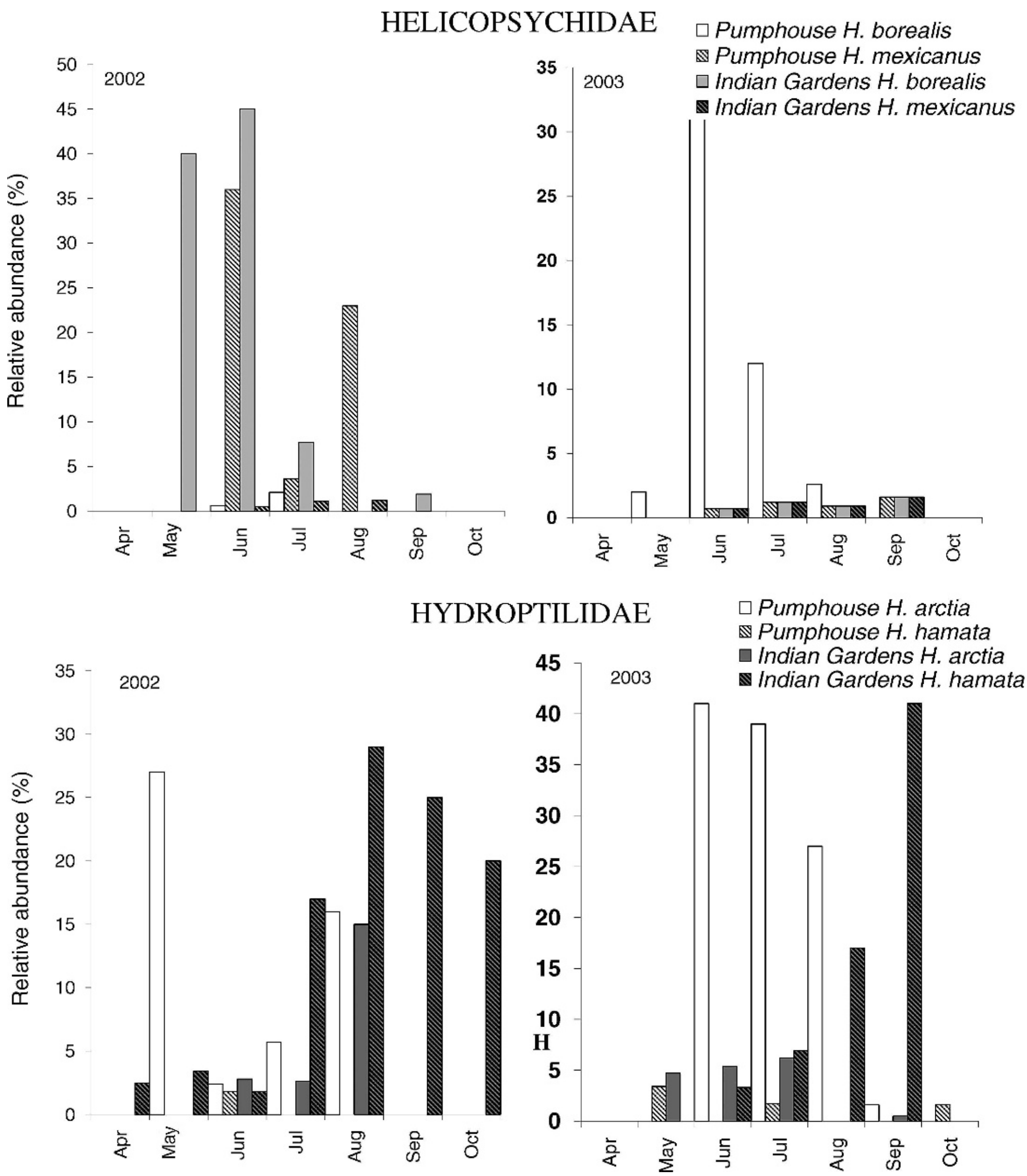

FIG. 1—Relative abundance of selected taxa of adult Helicopsychidae (*Helicopsyche borealis* and *H. mexicanus*) and Hydroptilidae (*Hydroptila arctia* and *H. hamata*) without a spring surge of water (2002) and following a spring surge of water (2003) in Oak Creek, Coconino Co., Arizona.

(696) also were higher in June 2005, following the 163 $m^3 s^{-1}$ surge of water in February of that year, than after the more constant spring flows in June 2002.

Differences in number of adults captured also occurred between years for several numerically important species. For example, *H. mexicana* made up 45% of the assemblage at Pumphouse Wash in 2002, while *H. borealis* made up <5% of the assemblage at this site (Fig. 1). After the 2003 spring surges of water, *H. mexicanus* was nearly absent from both sites, and *H. borealis* was dominant at Pumphouse Wash. Also, captures of adult *H. arctia* increased at Pumphouse Wash after the 2003 surge of water, while *H. hamata* decreased (Fig. 1).

Several other notable changes in composition occurred between years. *Oecetis disjuncta* was absent at both sites in 2002, but present at both sites in 2003 after the spring surge of water (Table 3). One-time pulses of *Apatania arizona*, *Oecetis arizonica*, and *Tinodes provo* occurred at Pumphouse Wash following the 2003 surge of water, but not during 2002. Pulses for *O. arizonica* and *T. provo* also occurred following the 2005 spring surge of water.

Discussion—Spatial and temporal differences in number and composition of captures of adult caddisflies occurred at Pumphouse Wash and Indian Gardens although there is <400 m difference in elevation and Indian Gardens is only 14 km downstream. The Sørenson's similarity index also suggested that assemblages at the two sites were not closely related. These differences likely resulted from higher air temperatures at the onset of emergence at Indian Gardens. Composition of assemblages between sites may also have been influenced by higher embeddedness of the channel at Indian Gardens. Pumphouse Wash had higher rates of capture of adults for lepidostomatids and limnephilids, while Indian Gardens had high rates of capture for hydropsychids. Blinn and Ruiter (2006) reported a greater percentage of lepidostomatids and limnephilids in streams throughout Arizona with a mean embeddedness of channel <10%, while streams with >32% had a greater proportion of hydropsychids. Barbour et al. (1999) reported hydropsychids to be more tolerant of poor water quality than lepidostomatids and limnephilids.

Striking differences between years with and without surges of water suggest these events play an important selective role in larval success and ultimately in number and composition of captures of adults. Anderson (1997) determined that emergence of caddisflies was coordinated with predicted surges of water and conditions of flow in stream channels in western Oregon. However, biotic interactions such as predation and competition may play a larger role in shaping structure of community in predictable flow regimes (Ward, 1992). Spring surges of water are important especially in reducing embeddedness of channel after base flows of the previous summer. Over time, channels become increasingly more embedded without these natural conditioning events. Surges of water also purge stream channels of high nutrient loads that accrue during base flows in summer. This is important especially in Oak Creek because high recreational demands in summer raise bacterial counts and nutrient loads in the system (Poff and Tecle, 2002).

In addition to those species collected in this study, Moulton et al. (1994) collected 22 females of *Oxyethira* during August 2002 at Indian Gardens and adults of *Agapetus boulderensis* and *Ithytrichia clavata* in 1993. This assemblage makes up >50% of all species of caddisflies reported from Arizona (Houghton, 2001; Blinn and Ruiter, 2006; P. Spindler, in litt.). Thus, Oak Creek has the highest reported number of species of caddisflies for any drainage in the state. Next highest drainages include the upper Little Colorado River (52), Black River (39), Fossil Creek (37), and Tonto Creek (31; Blinn and Ruiter, 2006).

Historically, May (1972) collected *Anabolia bimaculatus* in Oak Creek, while M. W. Sanderson collected four additional limnephilids (*Clistoronia maculatus*, *Limniphilus diversus*, *L. frijole*, *L. spinatus*), as well as *Agapetus boulderensis*, *Culoptila cantha*, *C. thoracica*, *Marilia flexuosa*, *M. nobsca*, *Micrasema onisca*, *Ochrotrichia spinosa*, and *Polycentropus variegatus* in Oak Creek during 1976–1984. None of the above 13 species were collected on any of our 45 collection dates. Most of these species occur in streams with low embeddedness of channels throughout Arizona (<6%; Blinn and Ruiter, 2006). The two limnephilids (*Hesperophylax magnus* and *Limnephilus lithus*) currently in Oak Creek occur in streams with a mean embeddedness of channel ≤24%. Sanderson collected 29 of the species we collected, seven of which had a mean embeddedness of channel >30% in Arizona. These distributional patterns and the relatively low Sørenson's similarity index (0.545) between collections by Sanderson and our recent collections suggest conditions in Oak Creek have been modified over the past several decades. *Protoptila balmorhea*, *I. clavata*, *Leucotrichia limpia*, *Neotrichia okopa*, and *Lepidostoma aporna* were not reported by Blinn and Ruiter (2006). With the inclusion of these species, the total number of species of caddisflies reported in Arizona is 109.

Simpson's similarity index showed considerable spatial differences in species assemblages along Oak Creek. The greatest change in Simpson's similarity index for assemblages occurred between the two lowest sites (Sedona and Page Springs) where intense ranching occurred. Additional reasons for these changes may relate to a suite of subtle interactions of larvae to thermal conditions, time and intensity of discharge, photoperiod, food, riparian composition and cover, and predators that affect rates and timing of ontogenetic events and composition of substrate. Usio (2000) reported significant reductions in aquatic invertebrates in the presence of crayfish. Pomeroy et al. (2000) showed higher processing rates by aquatic insects for native riparian vegetation compared to invading species such as *Tamarix ramosissima*, and Swan and Palmer (2004) detected a relationship between species of insects and rate of leaf-pack breakdown during summer.

Recently, Forest Guardians petitioned the United States Fish and Wildlife Service to list 12 species of caddisflies in Southwest Region as critically imperiled or imperiled (N. J. Rosmarino and J. J. Tutchton, in litt.). Four of these species (*Apatania arizona*, *Culoptila kimminsi*, *C. moselyi*, *Chimarra primula*) occur in upper Oak Creek. This recommendation further supports the need to preserve and protect the integrity of the Oak Creek drainage by regular monitoring. Other streams in Arizona that currently support these species include East Turkey Creek and the South Fork of Cave Creek in the Chiricahua Mountains, Little Colorado River and Rosey Creek in Greer, Arizona, the South Fork of the Little Colorado River, and Upper Tonto Creek (Blinn and Ruiter, 2006).

In conclusion, assemblages of caddisflies in Oak Creek change rapidly due to dramatic changes in life zones and channel conditions along the stream corridor. Spring surges of water play a selective role in larval success and ultimately in number and diversity of adults that are captured. We provide a baseline for monitoring change in health of the ecosystem in Oak Creek during the extended drought in the Southwest predicted by Seager et al. (2007).

We thank C. D. Blinn for the Spanish translation of the abstract. We also thank two reviewers who made comments on an early draft of the manuscript, especially D. E. Bowles. Northern Arizona University provided travel funds for this project.

Literature Cited

Aitchinson, S. 1989. A guide to exploring Oak Creek and the Sedona area. RNM Press, Salt Lake City, Utah.

Anderson, N. H. 1997. Phenology of Trichoptera in summer-dry headwater streams in western Oregon, USA. Pages 7–11 in Holzenthal. Proceedings of the eighth international symposium on Trichoptera (R. W. Flint and O. S. Flint, Jr., editors). Ohio Biological Survey, Columbus.

Barbour, M. T., J. Gerritson, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in wadeable streams and rivers: periphyton, benthic macroinvertebrates, and fish. Second edition. United States Environmental Protection Agency, Office of Water, Washington, D.C. EPA 841-B-99-002:1.

Blinn, D. W., and N. L. Poff. 2005. Colorado River Basin. Pages 483–538 in Rivers of North America (A. C. Benke and C. E. Cushing, editors). Elsevier Academic Press, Burlington, Massachusetts.

Blinn, D. W., and D. E. Ruiter. 2006. Tolerance values of stream caddisflies (Trichoptera) in the lower Colorado River Basin, USA. Southwestern Naturalist 51:326–337.

Bowles, D. E., S. G. Tiemann, and G. W. Easley. 2007. Caddisfly (Insecta: Trichoptera) assemblages of large springs and spring-runs in central Texas, USA. Pages 15–29 in Proceedings of the twelfth international symposium on Trichoptera, Mexico City, Mexico, 2006 (J. Bueno-Soria, R. Barba-Álvarez, and B. Armitage, editors). Ohio Biological Survey, Columbus.

Dehoney, B., and W. Gaud. 1983. Seasonal analysis of aquatic invertebrates and detritus in a small mountain stream in Arizona. Southwestern Naturalist 28:189–198.

Fisher, S. G., and N. B. Grimm. 1988. Disturbance as a determinant of structure in a Sonoran Desert ecosystem. Verhandlungen der internationalen Vereingung für Theoretische und angewandte Limnologie 23:1183–1189.

Hereford, R. 2007. Climate variation at Flagstaff, AZ-1950-2007. United States Geological Survey Open-File Report 2007-1410:1-17.

Houghton, D. C. 2001. Caddisfly (Trichoptera) records from the Apache National Forest, eastern Arizona. Entomological News 112:85–93.

May, E. 1972. An examination of the aquatic insect populations of Oak Creek, Arizona. M.S. thesis, Northern Arizona University, Flagstaff.

Moulton, S. R., II, K. W. Stewart, and K. L. Young. 1994. New records, distribution and taxonomic status of some northern Arizona caddisflies (Trichoptera). Entomological News 105:164–174.

Parrott, J. F. 1975. Seasonal analysis of aquatic insect populations in Oak Creek, Arizona. M.S. thesis, Northern Arizona University, Flagstaff.

Poff, B., and A. Tecle. 2002. Bacteriological water quality trend analysis in Oak Creek Canyon, AZ. Pages 431–436 in Proceedings: ground water/surface water interactions (C. L. Lant, editor). American Water Resources Association, Keystone, Colorado.

Pomeroy, K. E., J. P. Shannon, and D. W. Blinn. 2000. Leaf breakdown in a regulated desert river: Colorado River, Arizona, U.S.A. Hydrobiologia 434: 193–199.

Scott, J. 1982. Seasonal abundance and distribution of benthic insects at Pumphouse Wash and Chavez Crossing in Oak Creek, Arizona. M.S. thesis, Northern Arizona University, Flagstaff.

Seager, R., M. Ting, I. Held, Y. Kusnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N. Lau, C. Li, J. Velez, and N. Naik. 2007. Model predictions of an imminent transition to a more arid climate in south-western North America. Science 316:1181–1184.

Sørensen, T. A. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Kongelige Danske Videnskabernes Selskab 5:1–34.

Swan, C. M., and M. A. Palmer. 2004. Leaf diversity alters litter breakdown in a Piedmont stream. Journal of the North American Benthological Society 23:15–28.

Taydayon, S., N. R. Duet, G. G. Fisk, H. F. McCormack, C. K. Partin, G. L. Pope, and P. D. Rigas. 2001. Water resources data Arizona: water year 2000. United States Department of the Interior, Tucson, Arizona.

Usio, N. 2000. Effects of crayfish on leaf processing and invertebrate colonisation of leaves in a headwater stream: decoupling a trophic cascade. Oecologia (Berlin) 124:608–614.

Ward, J. V. 1992. Aquatic insect ecology. 1. Biology and habitat. John Wiley & Sons, Inc., New York.

Wilkinson, L. 1989. SYSTAT: the system for statistics. Version 5.1. Systat, Evanston, Illinois.

Submitted 7 January 2008. Accepted 1 September 2008.
Associate Editor was Jerry L. Cook.